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AGRICULTURAL LEDGER.

1897—No. 13.

REH.

[*DICTIONARY OF ECONOMIC PRODUCTS, Vol. VI., Pt. I., pp. 400-426, R. 67-70.*]

RECLAMATION OF REH OR USAR LAND.

Second Note by DR. J. W. LEATHER, *Agricultural Chemist to the Government of India, on certain experiments which have been carried out for that purpose.*

Other DICTIONARY articles that may be consulted:

Calotropis gigantea, *Vol. II.*, C. 190.
Sand-binding plants, *Vol. VI., Pt. II.*, S. 774.
Tamarx, *Vol. VI., Pt. III.*, T. 51-82.

also

The Agricultural Ledger Nos. 12 and 13 of 1893; 1 and 33 of 1896; 5 of 1897 (Reclamation of Reh or Usar land).

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(Mineral and Metallic Series, No. 10.)

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Second Note by DR. J. W. LEATHER, *Agricultural Chemist to the Government of India, on certain experiments which have been carried out for that purpose.*

In *The Agricultural Ledger No. 5 of 1897* (1) the area and the nature of the *Usar* lands of the North-Western Provinces has been explained; (2) the opinions of the several earlier observers has been quoted regarding the origin of the salts, and the means by which they have become accumulated in the surface soil; (3) the experiments which have been made with a view to render these lands culturable, and the results obtained, have been detailed.

1. ***Object of present Note.***—In the present Note the results of many analyses which the writer has made of *Usar* soils, from different parts of India, are discussed, and from these information is given regarding the nature and quantity of the salts present in the soils at various depths from the surface.

In the next place are given the results of experiments carried out by the writer on the germination and growth of plants in artificial *Usar* soils, containing known amounts of certain salts.

Lastly, the effects produced on *Usar* soils by the addition of such salts as gypsum, which have the power of neutralising Sodium Carbonate, are dealt with.

2. ***The Amount of Salts in Usar Soils.***—It is hardly necessary to point to the importance of determining both the nature and the quantity of the soluble salts in these *Usar* soils. Without a clear knowledge of these two items the subject cannot be understood.

It will be well to quote, in the first place, the analyses of the samples which have been made by others, for the papers containing the latter are not generally obtainable and they should be put on record.

REH. | **Reclamation of Reh**

In **Mr. Medlicott's** Note, published in the Reh Committee's Report, are the following:—

	Reh—Estimates in Soils.	Soluble salts, parts in 1,000.
	Akrabad (Aligarh), field No. 93:—	
A	1. Three inches cube of soil, including a thick crust of *reh*	18·80
A	2. Earth 2 feet below surface from a freshly dug hole within 6 feet of No. 1, surrounded by the same surface *reh*	2·44
A	3. Earth 6 feet from surface in the same hole	1·56
	Hydernagar, a hamlet of Nanon (Aligarh), field No. 769:—	
B	6. Six inches square by 2 feet from a small (6 feet square) bare spot, but without efflorescence, in midst of a rich crop, on same level, and equally irrigated from a well; water 6 feet from surface, not saline to the taste	3·88
B	7. A like sample from close by, under rich crop	·45
	Dasnah, the field of Mr. Michel's experiment:—	
C	8. Three inches cube of soil, no visible *reh*	1·13
C	9. Kankary earth 4 feet from surface	1·74
C	11. Clay film (papery) from a dry channel close by	4·07
	Sent by Captain Harrison, R.E.:—	
D	12. Shahpur (Cawnpur) field No. 199, "surface of *Usar* land in which an experiment in sub-soil drainage is being made"	2·73
D	13. Earth at 2 feet from surface	1·29
D	14. Earth at 5 feet from surface	1·51
	Gurioli (Farukhabad), field No. 322:—	
E	16. Surface	9·20
E	17. Earth 2 feet from surface	2·73
E	18. Earth 5 feet from surface	0·80
	Quoted from *Journal, Royal Asiatic Society, London*, Vol. XX., page 336, 1863: or *Sel. Govt. India, P. W. D.*, 42, page 43:—	
F	20. Four inches cube of soil	4·00
F	21. Sub-soil just over water	2·00

Mr. Ward, of the Royal School of Mines, London, analysed the following samples of *Usar* soils from the neighbourhood of the Western Jumna Canal:—

Depth of sample of soil.	No. 1, 40 feet from Canal.	No. 2, 5,000 feet from Canal.
	Per cent. of total soluble salts in soil.	Per cent. of total soluble salts in soil.
Surface	·2408	*3·0873
Two feet below surface	·1535	·3611
Four feet below surface	·0605	·4919
Six feet below surface	·0984	·6934

* This residue included—

Sodium Carbonate	·9038
Sodium Sulphate	1·0929
Sodium Chloride	1·1419

3. Before detailing the analyses of *usar* soils which I have made, a few words may be said regarding the methods of sampling and the analysis.

For the selection of samples I adhered to one method. A hole having been dug, the samples of soil were cut from the side of the hole between certain depths. Thus, for example, a sample taken between 1″ - 6″ will represent the average state of the soil from the surface to a depth of 6 inches below it ; one taken at 6″-2′ 6″ would be the average of the 2 feet of earth situated below the former. The soil having been "air-dried," it was shaken up with distilled water for a short time and then the whole thrown on a filter. In the earlier analyses it was attempted to allow the soil to settle, leaving a clear extract which could be boiled down ; but this method is quite impracticable with the majority of the *usar* soils. One property of most *usar* soils, to which reference will be made more fully in another paragraph, is that they will not settle in water perfectly ; even if allowed to stand for weeks together. The method of trying to obtain an extract of the salts by allowing the soils to settle was, therefore, soon given up and the extract obtained by filtration. The quantity of soil employed was in all, excepting the early cases, 100 grammes, which was digested in 500 c. c. of cold distilled water, and then the whole, including all the sand, thrown on to a perforated porcelain filter with a cloth covering. The first portions passing through are always muddy, but the *earth* sooner or later forms a perfect filter bed and the extract comes through clear. The muddy portion (which has already come through) is then poured back on the filter. By this means a clear extract is *generally*, though not always, obtained. It frequently happens, however, that the extract takes days to pass through, sometimes the whole will not pass through the filter at all, and also not infrequently a filtrate is obtained which appears only semi-transparent. Such extracts contain solid particles, which can be distinguished under the microscope, but they pass through the finest filters. The analysis of the extract is then carried out by the usual methods.

The figures in the statements are in all cases parts of salts per 100 parts of soil.

In calculating the results, all the chlorine is first considered as combined with sodium and then the sulphuric acid, so far as there is sodium for it to combine with. If any sodium then remains it is considered as carbonate. This assumption is based on the fact that Sodium Carbonate cannot exist in the presence of Magnesium or Calcium Sulphates or Chlorides. If these salts are brought in contact with solution of Sodium Carbonate, the latter is rapidly changed to Sulphate or Chloride as the case may be.

NORTH-WESTERN PROVINCES USAR.

4. The following are the examples of *Usar* soils which I have examined in the *Usar* plains of the North-Western Provinces and Oudh :—

REH. **Reclamation of Reh**

(1) Samples were taken in a *Reh*-covered plain near Bilhaur, Cawnpur District—

	Village Alipur near Bilhaur.			
	$\frac{26}{93}$ Soil on surface, 1" only.	$\frac{27}{93}$ Surface soil, 1" - 13".	$\frac{28}{93}$ 13" - 25".	$\frac{29}{93}$ Salt from surface.
Na_2Co_3 . . .	2·910	1·081	·236	9·67
TOTAL SALTS .	2 909	1·152	·250	9·73

(2) A piece of land near the village Kakwan, Cawnpur District. The spot selected was occupied, on the one hand, by a rice field, in which hole "A." was dug, whilst the second hole "B." was made in a piece of grass-land (village-waste) close by. A *bund* separated the two. The rice field was without any visible sign of the presence of salt, whilst the grass-land was covered with it. The soil was in both cases the same, namely, a clay. Moisture was found at a depth of 6 inches in both holes. In both holes the plant-roots were observed to reach below the bottom, that is, to a greater depth than 40 inches—

	Hole "A."			Hole "B."		
	1" - 6".	6" - 18".	18" - 30".	1" - 6".	6" - 18".	18" - 30".
Total Salt .	0·009	0·017	0·017	1·198	0·293	0·520
Sodium Carbonate .	0·009	0·011	0·013	1·064	0·261	0·491
Sodium Sulphate .	...	...	...	0·013	0·029	...
Sodium Chloride .	...	...	...	0·042	0·009	...

(3) At village Ibrahimpur, District Cawnpur, two holes were dug 16 feet apart. Hole A. was in *Usar*; no sign of grass roots were left; it was moist up to the surface and very damp at 3 feet; *kankar* was met with at 4 feet 6 inches.

Hole B. was in soil on which grass was growing; no salt was visible; plenty of roots were found down to 4 feet, *kankar* was situated at 3 feet. The soil was equally moist with hole A.:—

	Reh patch. Hole A.			Grass patch. Hole B.		
	1" - 6".	6" - 2' 6".	2' 6" - 4' 6".	1" - 6".	6" - 2' 6".	2' 6" - 4' 6".
Sodium Carbonate	1·728	·254	·098	·402	·387	·327
Sodium Sulphate .	·264	...	...	...	...	...
Sodium Chloride .	·046	...	...	...	...	...
TOTAL SALTS .	2·012	·292	·096	·428	·418	·395

(4) Near village Barauli, in District Farrukabad, I selected samples from a place where several patches of cultivation occurred in an *usar* plain.

Hole "A." was dug in a cultivated patch where the crop was good.

Hole "B." was made where the salts were efflorescing in large amount. It was 46 yards from "A." From it two samples were taken. Hole "C." was made where grass was growing well; it was 28 yards from "B." Hole "D." was dug where the grass was

covered with salt. It was 31 yards from "C." All the holes were in a nearly straight line.

	Hole "A."	"B."		"C."	"D."	
	1″ - 18″.	1″ - 6″.	6″ - 30″.	18 - 30″.	1″ - 6″.	6″ - 30″.
Total Salt . .	0·012	1·494	1·616	0·016	1·415	0·209
Sodium Carbonate .		0·087	0·159		0·140	0·022
Sodium Sulphate .		1·318	1·388		1·186	0·191
Sodium Chloride .		0·116	0·097		0·087	0·020

Kankar was found in hole "B." at 4 feet from the surface and in hole "C." at 3 feet, but none was found in the other holes within the depth to which they were dug. It will be observed that the principal salt in this place was Sodium Sulphate. The soil was a clay-loam.

(5) The next case was of a somewhat different type. The foregoing are examples of soil covered with salt, near to which there was cultivation. It often happens that the people apply the term *usar* to land on which no salt is visible and this is such an one. The land was situated near Rasulabad, District Cawnpur, and a healthy crop was growing in the middle of one of these *usar* plains. It occurred to me, therefore, to have a hole dug, the one end of which extended into the cropped land, the other into the *usar*. The hole was 3 yards long and 1 yard deep. On examination I could discern no difference in the soil at either end. The soil was sampled to a depth of 3 feet and the results of the analyses are as follows:—

	In fields.	In *usar*.
Sodium Carbonate . . .	0·099	0·277
Sodium Sulphate . . .	very little.	0·125
Sodium Chloride . . .	0·018	0·055

(6) The following shows the quantity of salt in some *usar* land at Barra, Cawnpur District:—

	1″-6″.	6″-3′ 6″.
Sodium Carbonate . . .	·884	·194
Sodium Sulphate . . .	·156	...
Sodium Chloride . . .	·052	·007

(7) Near Unao, a hole was dug in an "*Usar*" plain on which no salts were visible, and an average sample of the first 4 feet of earth taken:—

Sodium Carbonate	·095
Sodium Sulphate	·071
Sodium Chloride	·005

(8) At village Seora, District Unao, samples of soil were taken from an *usar* plain. There was some salt on the surface. The soil was a loam, and the sub-soil water was only about 4-6 feet beneath the surface.

	1″-6″.	6″-2′ 6″.
Sodium Carbonate . . .	·537	·203
Sodium Sulphate . . .	·108	·044
Sodium Chloride . . .	·020	·020

REH. | **Reclamation of Reh**

(9) An *Usar* plain near village Amramau, Unao District, soil clay, with some salt efflorescing and grass growing on most parts of it. The hole was dug 4 feet deep; the earth was moist, no *kankar* was met with. Sub-soil water at about 4 to 8 feet below surface:—

	1″-6″.	6″-2′ 0″.
Sodium Carbonate . . .	·079	·043
Sodium Sulphate . . .	·234	·949
Sodium Chloride . . .	·064	·185

(10) In an *Usar* plain, village Banthra, Lucknow District, were patches of cultivation, the remainder being mostly covered with grass and but little salt was visible. In the cultivation were patches of soil on which no crop was growing, this being a common characteristic of *Usar*. Two holes were dug: Hole A. in the *Usar* land; Hole B. in one of the bare patches in the middle of a crop The soil at Hole A. was a clay, very dry and hard, no *kankar* was met with. At Hole B. the soil was a clayey loam, moist and no *kankar* was met with:—

	Hole A.		Hole B.	
	1″-6″.	6″-2′ 0″	1″-6″.	6″-2′ 0″.
Sodium Carbonate .	·164	·121	·001	·042
Sodium Sulphate .	·032	·019	·011	·007
Sodium Chloride .	...	...	·004	·007

(11) At village Chinhat, Lucknow District, the *Usar* land is of a lighter colour than south of Lucknow. The cultivated land is quite light loam. The *usar* is clay, with but little salt on the surface, *kankar* generally lying on the surface—

	1″-6″.	6″-2′ 0″.
Sodium Carbonate . . .	·197	·119
Sodium Sulphate . . .	·046	·011
Sodium Chloride . . .	·048	·044

(12) On an *Usar* plain to the north of Bara Banki are patches of cultivation. Holes were dug, A. in the *Usar* which bore grass, B. in a field of *Arhar* (**Cajanus indicus**). The soil was similar in both cases, being a stiff clay. Salt was not visible at either place, nor was any *kankar* present. The soil at A. was perfectly dry and very hard, that at B. was damp and soft—

	Hole A.		Hole B.
	1″-6″.	6″-2′ 0″.	1″-6″.
Sodium Carbonate . .	·099	·127	·008
Sodium Sulphate . .	·023	...	...
Sodium Chloride . .	·008	·016	...

(13) At village Jarwal, Bahraich District, was a small area with salt on it. This was, however, not an *Usar* plain in the ordinary sense, being mostly under cultivation—

	1″-6″.
Sodium Carbonate	·012
Sodium Sulphate	·084
Sodium Chloride	·080

or Usar Land. (*J. W. Leather.*) **REH.**

(14) Samples of soil from two holes in the *Usar* Experimental "Reserve" at Gursikran, Aligarh, and from one hole in the land adjoining the "Reserve" contained the following amounts of salts:—

	Plot 35 in "Reserve."			Plot 24 in "Reserve."			Land outside "Reserve."		
	1″-12″.	1-3ft.	3-6ft.	1″-12″.	1-3ft.	3-6ft.	1″-12″.	1-3ft.	3-6ft.
Sodium Carbonate .	·172	·350	·271	·189	·089	·052	·588	·519	·243
Sodium Sulphate .	·073	·088	·055	·112	·042	...	·055	·042	...
Sodium Chloride .	·169	·187	·029	·385	·280	·058	·023	·023	·005

Grass was growing on Plots 24 and 35, but none where the other hole was made.

(15) Samples of soil were taken in 1896 from four holes in the same "Reserve" at Gursikran, Aligarh. Some land was ploughed up in 1895 and wheat was sown in the cold weather of 1895-96. It was then found that on some parts the wheat was most luxuriant, whilst on other places not a blade of corn grew. Two of the holes, Nos. 1 and 2, were in one plot of wheat, Nos. 3 and 4 were in another plot. In each case the pairs of holes were within a couple of feet of one another. Where holes 1 and 3 were made the wheat was excellent, whilst at the spots where holes 2 and 4 were made no wheat grew at all.

	Hole 1. Where Wheat grew well.	Hole 2. Where no Wheat grew.	Hole 3. Where Wheat grew well.	Hole 4. Where no Wheat grew.
1st Depth.	1″-6″.	1″-6″.	1″-6″.	1″-6″.
Sodium Carbonate .	·044	·193	·137	·251
Sodium Sulphate . .	...	...	...	...
Sodium Chloride . .	·021	·010	·062	·008
2nd Depth.	6″-1′ 6″.	6″-1′ 6″.	″6-1′ 6″.	6″-1′ 6″.
Sodium Carbonate	·061	·416	·043	·332
Sodium Sulphate . .	...	...	·013	...
Sodium Chloride . .	...	...	·005	·012
3rd Depth.	3′ 6″-4′ 6″.	3′ 6″-4′ 6″.	3′ 6″-4′ 6″.	3′ 6″-4′ 6″.
Sodium Carbonate .	·072	·240	·340	·237
Sodium Sulphate . .	...	...	...	...
Sodium Chloride . .	·017	·012	·023	...

REH. **Reclamation of Reh**

(16) Samples of soil from 6 holes in the *Usar* "Reserve" at Cherat, Aligarh, contained the following quantities of salts. Grass covered the land generally :—

	Hole 1.	Hole 2.	Hole 3.	Hole 4.	Hole 5.	Hole 6.
1st Depth.	1"-12".	1"-12".	1"-12".	1"-12".	1"-12".	1"-12".
Sodium Carbonate	·195	·647	·416	·813	·366	·325
Sodium Sulphate .	·013	·080	·038	·063	·172	·102
Sodium Chloride .	...	·095	·023	·071	·085	·012
2nd Depth.	1-3 ft.	1-3 ft.	1-3 ft.	1-3 ft.	1-3 ft.	1-3 ft.
Sodium Carbonate	·291	·585	·528	·881	·297	·431
Sodium Sulphate .	·024	·072	·023	·060	·094	·109
Sodium Chloride .	...	·102	·020	·092	·050	...
3rd Depth.	3-6 ft.	3-6 ft.	3-6 ft.	3-6 ft.	3-6 ft.	3-6 ft.
Sodium Carbonate	·105	·059	·115	·054	·022	·208
Sodium Sulphate .	·021	...	...	·029	·011	·013
Sodium Chloride .	·041	·008	·012	·153	...	...

5. Looking over the analyses of these various samples, it will be seen that generally the salt which is present in greatest quantity is Sodium Carbonate. In two cases only (Nos. 4 and 9) was Sodium Sulphate the principal salt; in four other cases it was present to the extent of ·1 to ·2 per cent.

In no case was Sodium Chloride present in considerable amount In the soil of Plots 24 and 35 at Gursikran this salt was present in amount varying from 1 to ·3 per cent.; but this is exceptional.

Also it will be seen that where the salts are present in any material quantity, the greater part is present in the first few inches of surface soil and the proportion then rapidly diminishes.

On the other hand, in those soils in which grass or other plants are growing, the salts are much more evenly diffused. This is very clearly seen in the case of the samples taken at Gursikran (Nos. 14 and 15) and Cherat (No. 16). In No. 15 at Gursikran (Holes 2 and 4) nothing was growing at the time the samples were taken, but grasses had been allowed to grow for many years until the year 1895.

PANJAB USAR.

6. In November 1895, I visited the Districts Karnal, Ferozepur, Muzaffargarh and the Chenab Canal in the Panjab, in all of which *Usar* land occurs. It is also called *kalrati* land, and the salts are called *kallar*. For the sake of uniformity the term *Usar* land will be adhered to.

With the exception of the *usar* at Muzaffargarh, which is low lying near the River Chenab, these Panjab tracts consist of very similar land to the *usar* of the North-Western Provinces and Oudh; they are level lands of yellow alluvium containing a high proportion of clay.

The following notes describe the *usar* of Ferozepur, the land in the neighbourhood of the Chenab Canal, and Muzaffargarh, the chemical analyses of the soils being added. In addition to these some analyses of *usar* soil from Lahore are given.

7. ***The Chenab Canal.***—I travelled over the following route on this canal: Killa Ram Kaur, Vaniki, Kolotara, Saidnagar, Sagar, Nanuana, Marh, Mochiwalla, Sangla.

Speaking generally there is a distinct difference between the land which I saw on this route from Killa Ram Kaur to Sagar and that which I examined between Sagar and Sangla.

In the former indicated country the village sites appear to be generally on a soil of good brown loam, well cultivated and bearing a fair number of trees. In between them there are large stretches of a greyish clay. These are the so-called *kalrati* lands. They are rarely cultivated and a few *babúls*, etc., are the only trees which break their monotony. The vegetation is scantier than on similar land in the North-Western Provinces, but they are rarely cut up by surface drainage (perhaps because the rainfall is lighter).

But, although these *kalrati* lands have been considered to be unculturable on account of the salt they contain, I found only very slight evidence of the presence of such injurious substances, indeed it was only here andthere in the water-courses that any indications of efflorescing salts were to be seen.

The following are the analyses of samples of soil taken at four places in uncultivated *kalrati* land; there is in addition one sample of *cultivated kalrati* land and one of a good loam near some *kalrati* land at village Kaliki.

(*a*) and (*b*) were taken in land in village Kolotara at a spot 200 yards north-north-west of the 29,000 feet stone on the Gajar Gola Rajbaha. No grass was growing and no salt was apparent on the surface, but some little salt was to be seen in the water-courses.

It was about the worst spot I could find in the neighbourhood. The analyses show that there was some amount of Sodium Sulphate, with much smaller proportions of Carbonate and Chloride. The land in the vicinity was being brought under cultivation. (*c*) and (*d*) were taken from two spots near the Sagar Bungalow in *kalrati* land, and they contain practically no salts at all. (*e*) was selected from the surface soil of a cultivated field of *kalrati* land near sample (*c*). (*f*) is a sample of good loam from a field near Sagar Bungalow (*g*) and (*h*) are from village Kaliki, 2 miles north-west of Nanuana Bungalow. This land is of the same nature as the foregoing, is a stiffish clay, and is termed *kalrati* by the people. There was no vestige of salt on the surface, and, as will be seen, the surface soil contained practically no harmful salts; whilst the sub-soil contained a little Sodium Sulphate. Nor was there in the vicinity any salt in the

water channels or on the spots where water must occasionally lodge after rain. Sample *(i)* was from a field of good loam from village Kaliki.

In the country south-east from the Nanuana Bungalow, in villages Burj Dara and Dinga, the cultivated lands appeared to be somewhat stiffer than at Kaliki, whilst the grazing areas seemed to be of a distinctly lighter nature than the *kalrati* clays. A little salt was present in one or two of the irrigating channels due possibly to the well water used; but it had not produced the bare patches in the fields which are so characteristic of the North-Western Provinces *Usar*—

	Kolotara.		Near Sagar Bungalow.				Village Kaliki.	
	200 yds. N.-N.-W. of 29,000 ft. stone on Gajar Gola Rajbaha.		600 yds. S.-E. from R. D. 119.	200 yds. S.-E. from R. D. 119.	600 yds. S.-E. from R. D. 119.	Good loam.	2 miles N.-W. of Nanuana Bungalow.	
							Kalrati land.	Good loam.
	(*a*) 1"-6".	(*b*) 6"-1'6".	(*c*) 1"-6".	(*d*) 1"-6".	(*e*) 1"-6".	(*f*) 1"-6".	(*g*) 1"-6".	(*h*) 6"-1'6".	(*i*) 1"-6".
Sodium Carbonate .	·045	·171	*Nil.*	*Nil.*	·041	*Nil.*	·007	·054	*Nil.*
Sodium Sulphate .	·801	·475	·034	*Nil.*	*Nil.*	*Nil.*	·076	·219	*Nil.*
Sodium Chloride .	·146	·040	·011	·011	*Nil.*	·005	·005	·017	·029

8. In a Note written by **Mr. M. F. O'Dwyer, C.S.**, in 1894 the *kalrati* lands of this locality are thus described :—

"The villages in the 1st Division of the Chenab Canal irrigating from the Vaniki, Gajar Gola, and Kalianwala Rajbahas and the Kot Nikka branch, have, as a rule, a large part of their areas affected by *kallar*, otherwise known as *shor* or *reh*, when it takes the form of a white efflorescence on the surface. The soil in which these sodium salts are found in deposit is generally a stiff clay, sourish or salt to the taste, and is known as *kalrati* in contrast to the sweet clay known as *rohi* which is the best of all soils. The *kallar* or *kalrati* land sometimes rests on a stratum of *kankar*. Previous to the opening of the Chenab Canal no attempt was made to cultivate this sour clay except here and there in low hollows, where drainage water collected. It was too stiff and thirsty to grow *barani* crops with the small rainfall of this tract, and the zemindars were averse to sinking wells in it,

partly owing to the difficulty of boring through a stratum of hard clay, with perhaps layers of *kankar* sandwiched in here and there, but chiefly because they believed that the land could not be made productive even with well water, which, they said, would bring the *reh* or *shora* to the surface and render the land worthless. In fact in previous settlements this land, which in round numbers embraces over one-third of the total area of the Wazirabad Tahsil, and about one-fourth of Hafizabad, was recorded as *ghairmumkin, i.e.*, unculturable waste."

I had, therefore, expected to meet with a state of things similar to those in the North-Western Provinces and was somewhat surprised to find so little evidence of salts in the soil. The analyses leave no doubt, however, that, excepting here and there, this soil is not (at least at the surface) seriously impregnated with sodium salts. Like all this Indian alluvium, the sub-soil drainage is liable to be imperfect, more especially in the absence of vegetation, and probably on this account all these waste lands contain a small proportion of sodium salts. It cannot be too carefully borne in mind that, although this *reh* is in all probability the refuse sodium salts of the soil, liberated but not assimilated by plants, and although. also, the amount of water withdrawn from below by plants in cultivated areas and dissipated into the atmosphere is greater than where vegetation is absent or but poor, there is at the same time in cultivated land a much more perfect *circulation* of water, the roots descending, as they do for many feet, keep the sub-soil open, and the natural conditions for drainage are fulfilled. These *kalrati* lands certainly appear in some cases to be quite different from the cultivated lands round the villages; they are generally clays, and it appeared to me that herein lies possibly the explanation why they are generally left for grazing; they are more difficult to plough and cultivate and the people will naturally choose the loams for raising produce so long as there is any choice in the matter. With the advent of a plentiful supply of water, such as is assured by the Chenab Canal, their cultivation of this land is rendered comparatively easy and, although there seems to have been at first a belief among the people that such land would not produce crops, that creed has now broken down and doubtless they will be cultivated in the future, a change which will probably be very beneficial to them. Touching this point I quote again from Mr. O'Dwyer's Note—

"As remarked by Fateh Ali Shah, Zilladar, in his report, even when the canal was opened in July 1887, the zemindars thought it useless to attempt breaking up this land even with canal water, and it was not till a few of the more enterprising set the example by growing rice with success on *kallar* land, that their opposition was overcome. Thereafter there was a general movement to growing rice on such lands with canal irrigation, which is still extending, and many villages with a light loamy soil far superior to the *kallar* for *barani* or well cultivation, now envy their neighbours the possession of the large *kallar* areas, which till the advent of the canal were regarded as worthless even for grazing."

"So slow, however, are the people to give up the old tradition, that even after they had seen good crops of rice grown on *kallar*, they

fell back on the opinion that such land would after one or two croppings become exhausted and afterwards become quite barren. When I joined the Settlement in September 1889, this was the universal cry of the Hafizabad zemindars. When I now confront them with the fact that the same land has gone on yielding excellent crops of rice for six or seven years in succession, they have to give up that position, but fall back on another and at present more plausible one, *viz.*, that this *kallar* land will grow only rice, and that in yearly decreasing quantities, and will not grow spring crops such as wheat or barley."

"Meantime other *kallar* villages (there is an extensive group of them from Jalalpur to Pindi Bhattian running parallel with but beyond the influence of the river) which have not yet received any canal irrigation, are clamouring to have canal water extended to them, and complain that, unless this is done, they will be completely broken down, as tenants are deserting them for the more profitable and less laborious cultivation on the canal."

9. ***Nanuana to Marh.***—For several miles after leaving Nanuana, the soil on the south-eastern side of the canal is in many parts fairly clayey. Passing them to the other (north-western) side of the canal, I found that the soil becomes somewhat lighter in nature as one approaches Mochiwalla Bungalow, and there were occasional appearances of salt in the canal banks. But the land, even in the depressions or holes, did not exhibit any accumulations of salts, as is generally the case in *Usar* land. Here and there the surface had the thin black crust, which all the more clayey soils exhibit in the waste areas.

Near Mochiwalla and thence more or less all the way to Marh there are more indications of salts in the surface soil than I saw elsewhere on this canal. There is a fairly strong patch on the north-western side of the canal at Mochiwalla, between it and the Rajbaha, but further out in the waste land the salts disappear again and the soil seems to be somewhat more clayey. In the following statement of analyses those marked (*a*) and (*b*) are from a hole close to the bridge in the area between the canal and the Rajbaha. Here there was a very considerable amount of salts in the soil, most of which was at the surface.

From Mochiwalla to Marh the soil appeared to become decidedly less clayey and a newly sown hedge of *shisham* near the canal was flourishing (excepting in places), and showed excellent growth for the eight months since it was planted. But here and there near the road little patches occur, where salts have effloresced on the irrigation channel of this hedge, and the trees have died away here in great measure. To the west of the Marh Bungalow the soil is everywhere a yellow loam and even sandy in places. Nevertheless there are in many of the fields very distinct signs of salt efflorescence exhibited in some places by the weak patches in the *rabi* crops, whereas in others the salts had effloresced on the surface. The analyses (*c*) and (*d*) are of soil taken from a level place (about 50 yards north-west of the

Railway and 100 yards north of the road to Marh), next to a field where a considerable bare patch had occurred in a turnip crop. The soil was a red loam. No salt was apparent on the surface. Here there was hardly any Sodium Carbonate; the greater part of the salts consisted of Sodium Sulphate.

Further to the west of the village Marh there is an area much more seriously affected and which has all the characteristics of the North-Western Provinces *Usar*. The salts had cropped out here badly in places and the soil was somewhat clayey.

For some miles the bank of the canal between Marh and Sangla has proved to be readily attacked by the water—the soil does not bind and the salts crop out badly everywhere on the banks. A new bank is being formed by allowing the canal to deposit silt in tanks on the north-western side of the canal. In the bottoms of those of the tanks to which water had not yet been admitted, the salts had effloresced.

Analyses *(e)* *(f)* and *(g)* in the following statement are those of soils taken from a spot south of Sangla Bungalow. It is fairly representative of the sort of land in that neighbourhood. Here again there was but little Sodium Carbonate, the greater part of the salts consisted of Sodium Sulphate—

	Mochiwalla Bungalow.		Half mile W. of Marh Bungalow.		Sangla Bungalow Compound.		
	(*a*) 1″-6″.	(*b*) 6″-1′6″.	(*c*) 1″-6″.	(*d*) 6″-1′6″.	(*e*) 1″-6″.	(*f*) 6″-1′6″.	(*g*) 3′6″-4′6″.
Sodium Carbonate .	2·175	·045	*Nil.*	·057	·120	·148	·035
Sodium Sulphate .	1·318	·185	·256	·557	1·312	·944	·277
Sodium Chloride .	·624	·093	·163	·280	·654	·572	·175

10. From the foregoing it will be evident that, judging by the state of the surface soil, the *kalrati* lands in the vicinity of the upper part of the Chenab Canal, there is very little salt at all. Even with half a per cent. of Sodium Sulphate it is doubtful, for reasons set forth in paragraph 32 of this paper, if it would occasion serious damage to crops. It is also probable that the more vigorously such land is cultivated, the more perfectly will these salts be prevented from accumulating at or near the surface, even if they do not entirely drain away.

Within the area further down the canal, *i.e.*, from Mochiwalla westwards, there seemed to be much more salt in the soil. At the same time it appears to be principally Sodium Sulphate with small proportions of Carbonate. The amount of Chloride appears to be larger than in the North-Western Provinces and Oudh soils.

11. ***Muzaffargarh Usar.***—In the Muzaffargarh District, there is much evidence of *Reh* in the *khadir* land of the Chenab River. This *Reh* bears the characteristic appearances of "black

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alkali" as the Americans call Sodium Carbonate; it appears in both cultivated as in uncultivated land, and it was frequently a matter of surprise to me that crops grow in this land at all. The soil is, however, all river silt of recent origin and contains a high proportion of sand in the sub-soil. In some of the grazing grounds I found pure coarse sand thrown up by moles or worms. Moreover, the land is liable to occasional floods from the river Chenab, as occurred in 1894. Hence it is probable that the salts are caused to diffuse through the soil annually more or less and only concentrate at the surface for comparatively short periods of time. The sub-soil water level is everywhere near the surface, averaging 5-10 feet.

The following samples of soil were selected and analysed:—(*a*) To the west of Muzaffargarh there is a bad piece of *usar* which affects alike cultivated and uncultivated land, though, as usual, the salt appears in greater quantity on the latter.

Hole 1 in grazing land where water flows or lies late; no grass grew just here though the main portion was covered with a tall coarse grass. There was cultivation, with well irrigation, 100 yards off. Water at 10 feet from surface. The soil consisted of river silt with no clay, and moisture existed up to the surface.

Hole 2 in the same grazing ground, though half mile further north; the conditions were similar to those at Hole 1, but the salt seemed to be present in larger amount. Water probably lies here after the rains. The soil was somewhat drier than at Hole 1; moisture appeared at about 8 inches below the surface.

The analyses are set out in the following statement. At both places there was a large amount of both Sodium Carbonate and Sulphate; more than sufficient to damage crops.

(*b*) At a village Gazanfargarh, about 18 miles south of Muzaffargarh, there is a piece of bad *usar*, which is a regular swamp and appeared to extend a considerable distance. The samples from "Hole 3" in the statement were taken at a fairly bad place. The soil consisted of dark-coloured silt, not clay, with moisture up to the surface. This area is not cultivated, but used as a grazing land and appeared to be subject to periodical submersion by water. A part of it was occupied by a *jhil* at the time of my visit. A sample of average good cultivated land was taken at the village Mohammadpur, near Gazanfargarh, and the analysis is labelled Hole 4 in the statement.—

	Muzaffargarh, Hole 1.		Muzaffargarh, Hole 2.		Gazanfargarh, Hole 3.		Mohammadpur, Hole 4.
	1″-6″.	6″-1′6″	1″-6″.	6″-1′6″.	1″-6″.	6″-1′6″.	1″-6″.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Sodium Carbonate	3·071	·197	·733	·337	1·043	·248	*Nil.*
Sodium Sulphate	1·407	·115	·545	·502	1·583	·368	·088
Sodium Chloride	·076	·035	·163	·046	1·255	·017	·052

But all the way from Muzaffargarh to Gazanfargarh there is much *Reh* in the fields, and I was surprised to see so much cultivation. There were many cultivated fields which apparently had as much *reh* in the surface soil, as would have prevented their cultivation in the North-Western Provinces. This is, I believe, not due to any superiority in methods of cultivation or to the presence of an especially good class of cultivator. In fact the reverse was rather the case, the implements and cattle being of a worse class than in most parts of the North-Western Provinces, and the cultivation generally anything but good. Nor is the nature of the salts of a less pernicious description than in other affected places, for, as the analyses show, they consist of Sodium Carbonate and Sulphate in about equal amount. I believe that it is in a great measure due to the presence of a large proportion of coarse sand in the sub-soil and the consequent open nature of the land, together with a plentiful supply of sub-soil water near the surface, thus probably allowing the salts to become periodically diffused more or less, that the cultivation is as good as it is.

12. ***Ferozepur District.***—In this district I saw (during a journey from Ferozepur to Jellalabad) but little *usar* or *kallar* land. Near Ferozepur some of the land of one village was affected, and again at Jellalabad there was an area of *usar* land.

From the analyses of these soils (*vide* the following statement) it will be seen that the amount of salts present in the surface soil of the cultivated fields near Ferozepur was not inconsiderable, though there was at the same time no Sodium Carbonate. The land at Jellalabad contained very considerable quantities of all the three sodium salts:—

	Usar soil from cultivated field in village near Ferozepur.	*Usar* soil from uncultivated land at Jellalabad, Ferozepur District.	
	1″-6″.	1″-6″.	6″-1′6″.
Sodium Carbonate . .	*Nil*.	1·688	·142
Sodium Sulphate . . .	·834	4·165	·520
Sodium Chloride . . .	·204	1·400	·087

13. ***Changa Manga.***—Outside the Changa Manga Fuel Reserve the land is a bare grazing area, with but little scrub jungle, and the soil was dry and very hard at the time of my visit. The following analysis shows the amount of salts in the surface soil per cent.:—

Sodium Carbonate.	Sodium Sulphate.	Sodium Chloride.
Nil.	·017	·011

This land may be said to be practically free from Soda salts.

14. ***Lahore.***—There is some salt present in the surface soil of the Lahore Horticultural Gardens, and the following analyses of two samples of this land may be quoted. It will be seen that it consists principally of Sulphate and Chloride with minor quantities of Carbonate :—

	Sodium Carbonate.	Sodium Sulphate.	Sodium Chloride.
1	·043	1·059	1·364
2	·143	·277	·364

15. As regards these *usar* soils in the Panjab one may now draw one or two conclusions :—

First.—It will be seen that all along the Chenab Canal, and at Lahore, Ferozepur and Changa Manga, the principal salt present is usually Sodium Sulphate, though at Mochiwalla on the Chenab Canal, the major part of the salts was Sodium Carbonate. At the Lahore Gardens there was a good deal of Sodium Chloride.

In the *khadir* of the Chenab River in Muzaffargarh District there was a considerable amount of both Sodium, Carbonate and Sulphate.

Secondly.—It may be safely asserted that much of the land which is termed *kalrati* in the neighbourhood of the Chenab Canal does not contain much if any of these Sodium salts. It is a heavy clay soil, difficult to cultivate, and probably for this reason the people have raised their crops on the lighter loamy soils.

Thirdly.—As in the case of the North-Western Provinces *Usar*, the greater part of the salts exists in the surface soil.

USAR IN GUJARAT, BOMBAY.

16. In the Kaira District of Gujarat, Bombay, there is a small area of land which is affected by accumulations of salts in the surface soil, and the following gives a description of it. It is a peculiarly small well-defined area in a country which is otherwise free from *usar*, and is in this respect different from that found in the North-Western Provinces and Panjab.

I travelled with Mr. Ozanne from Dakor along the main road to Kapadvanj, and back, and visited a number of villages on each side of the road. Evidences of salty efflorescence are to be found in many of these villages, but with the exception of the tract, presently to be defined, the salty patches in the other villages are of no moment at all.

The main tract of land which is affected by this salty efflorescence, and which the people call *usar*, seemed to me to be very well defined. It commences a little to the north-east of Lasundra and runs westward towards the Mohar River.

As to the other villages which I visited, Chiklod, to the east of the main road, contains no *usar*, in Navagam, Jaloia and Thunchal to the north-west of Kapadvanj, I found small patches of salty efflorescence in one or two depressions which are tanks in the rains; in villages Mirampur, Ambliara, Wasna, Daiap, I found no *usar*. Between Daiap and Sikandra Porda there was a small area which was slightly affected. This was near a tank.

In the villages Laksmanpura (excepting the northernmost part), Samalpura, Chetasamba and Ajupura there was likewise no *usar*. The only area which was at all badly affected was that alluded to and includes Lasundra, Ladvel, Laksmanpura (northernmost part), and Kathana, and seems to be coincident with a drainage area which occupies the same ground.

17. Regarding the nature of the soil of this part of the Kaira District, it varies from a description of black soil to a light yellow one.

Although the junction of these soils is not in any one very distinct direction, it is nevertheless very well marked everywhere, the change being complete within a few yards.

At Chiklod the soil is black for the most part, and it is the same to the eastern side of Lasundra, whilst the villages Laksmanpura, Samalpura, Chetasamba, Ajupura are all on this black soil. On the other hand, the villages Kathana, Ladvel, Lasundra (west part), Daiap, Dana, Ambliara, Mirampura, are all on a light yellow soil. The same sort of soil lies to the north-west of Kapadvanj across the Mohar River.

Regarding the black soil of the district, it is in some respects quite different from the true "Black Cotton" soil, although it resembles it in others.

It has no loose surface soil, but is hard and impervious instead; it cracks like the "Black Cotton" soil, but the cracks are much smaller; in the grazing lands there are numbers of large holes 1 foot and 2 feet deep where the water has last lain. *Kankar* underlies it in many places.

The yellow soil is similar in colour and general character to that found in the North-Western Provinces. It is distinctly sandy for the most part, and I saw no large area which could be called clay, though here and there the soil of a field approaches to that character. *Kankar* underlies these soils also very generally.

As usual, the thickness of the *kankar* varies very much indeed; in some places it is only a few inches thick, in others it is many feet and in one place, Samalpura, it measured some 25 feet in thickness. But this is exceptional, and generally it was 1 or 2 feet in such holes as I came across or had specially dug.

18. The water level of this area varies very rapidly indeed. At Ladvel it was, at the time of my visit, 11 feet from the surface, at Chetasamba in some grazing land, it was only 2 feet, at Samalpura it was some 30 feet, whilst at Ajupura it was 60 feet from the surface.

19. Turning now to the samples of soil which I collected (*vide* Statement attached), the two from Lasundra were taken from holes about 40 feet apart in some land which was apparently affected by salts. Field No. 723 (original survey) was under cultivation; the rice of the last monsoon had been all right, but the gram (**Cicer arietinum**) crop was more or less a failure. It was then on the ground and the hole was dug where the crop had failed. The surface soil 1″-8″ was hard, dry and clayey; moisture met with at 1 foot and soil sandy loam from 1′-2′ 6″, then clay. Field No. 719 (original survey) was lying waste and was in a much worse condition

as regards salt efflorescence than No. 723. The top soil was sandy loam and clay was met with at 4 feet. Both these fields are close to the main road. It will be seen from the Statement that hardly any soluble Sodium or other salts was in the surface soil of field No. 723, whilst there was about two-tenths per cent. of Sodium Chloride and rather more Sodium Carbonate in the surface soil of field No. 719. The sample taken at village Chiklod was not *usar*. It was from a piece of grazing ground which the people said was very poor, but there was no outward sign of salt on the surface. There is, as the analysis shows, some Sodium Chloride, but nothing else worth mentioning. The other eight samples, three from Ladvel, one from Laksmanpura and four from Kathana, represent the state of the worst parts of the drainage channel. The three samples from Ladvel were from a hole in grazing land where no grass grew. It was apparently a good loam down to 2 feet where it became more clayey. The surface soil contains over half a per cent. of both Sodium Chloride and Sodium Carbonate, whilst there was very little Sodium Sulphate, but, as the second sample shows, the soil below 6 inches becomes rapidly purer, the proportion of Sodium Chloride amounts to only about one-tenth per cent., the Sodium Carbonate having decreased to less than four-tenths, whilst at 1 foot 6 inches deep the Sodium Carbonate is less than two-tenths per cent.

The sample from Laksmanpura contained over two per cent. of Sodium Chloride with very little else.

The chief feature of the soil in the two fields in village Kathana from which samples were taken, is the Sodium Chloride they contain, whilst the amounts of other salts is quite subordinate. As in the Ladvel soil, the major portion of the salt is in the surface soil.

20. Thus in the case of this land the predominating salt is Sodium Chloride accompanied by smaller amounts of Sodium Carbonate; Sodium Sulphate is present only in very small amount in the majority of the samples.

SALTY LAND IN THE DECCAN, BOMBAY.

21. In the neighbourhood of the Nira Canal there are certain areas which have become affected with salty accumulations. Under instructions from Government I examined this land in 1894, and the following extracts from my report give a description of the conditions under which the area was existing at the time of my visit. In the country contiguous to the Nira Canal I inspected six areas which were pointed out to me as having been injured by the canal.

22. There is a remarkable similarity between all the six cases.

It is striking as one passes along the road (parallel to the canal which runs from west to east) how the rotation of (1) hill almost bare of soil, (2) reddish soil with rock, near the surface, (3) black soil, deep in most places in the centre of the valley, recurs. In the same way the canal seems to pass (1) through hard rock, (2) through soft rock called "Murum," (3) over the black soil of the *nalla*. Such was what I observed as I passed from Baramati to Nira, and here are

Analyses of Soils from the Kaira District, Gujarat.

	115.	116.	117.	131.	132.	133.	130.	126.	127.	128.	129.
	Lasundra.		Chiklod.	Ladvel.			Laksmanpura.	Kathana. Rice land.		Kathana. In drainage area.	
	Field No. 723, Surface Soil.	Field No. 719, Surface Soil.	Field No. 282, Surface Soil.	Surface Soil. 1″-6″.	Sub-soil. 6″-1′ 6″.	Sub-soil. 1′ 6″-2′ 6″.	Surface Soil. 1′-6″.	Surface Soil. 1″-6″.	Sub-soil. 6″-1′ 6″	Surface Soil. 1″-6″.	Sub-soil. 6″-1′ 6″.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Sodium Sulphate	...	·021	·029	·098	·039	·030	·206	·145	·033	·345	·114
Sodium Chloride	·005	·196	·187	·561	·133	·153	2·244	1·331	·377	1·350	·433
Sodium Carbonate	·005	·263	·026	·562	·375	·183	·100	·083	·063	·118	·073

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included the areas of villages Pandare, Wadgaon, Karanje and Nimbut. All the six areas examined are in the immediate vicinity of a *nalla*. The soil in each of the affected areas is almost entirely black. They are all on the "down stream" side of the canal, and in all the cases the greatest injury appears to commence at some little distance, 50-150 yards from the canal, from whence it extends. The areas are all very badly water-logged, and in all, salty patches occur here and there on the surface. Lastly, the erosive action of storm-water appeared to me to be serious. The Nira Canal commands a gross area of 300,000 acres, of which 107,000 acres are irrigable and it cannot be spared. It is necessary, therefore, to consider how the evil, which I understand Government admit is due to this canal, may best be contended with. Leaving out of account for the time being the source of the salt accumulations, the first question, "What is the cause of the water-logged condition," may be dismissed readily. I have said that I understand Government attribute this to the canal, and the evidence which I obtained from the Canal Supervisors, both of whom have resided in these districts for many years, coincides with this view. They both showed me the fields which they could remember as being fertile, and which are now barren.

The Supervisor of the Nira section of the canal seemed to me an exceptionally observant man, for he showed me how he used certain objects as land-marks by which he could roughly measure the rate at which the land had been going out of cultivation. Indeed no one going over these lands could well come to any other conclusion, and I certainly agree with it. The next question is, whether the leakages can be stopped either partially or entirely. It is, however, one rather for the Canal Department to deal with, and I shall not attempt to discuss it.

23. Then, as to the area which is affected, and also the question, "Is that area increasing?" On this point, I understand, there is no information, and to my mind it is quite as important as the one which I shall presently consider, namely, the means to be taken to overcome the difficulty. Nothing has helped me so much in making my observations as Mr. Ozanne's notes. With these he includes sketches of the fields which he visited, and I was thus enabled to compare their present state with that of 1889. It was by their aid that I could determine the fact that areas under the Mutha Canal, noticed in another part of the Report, which were in a bad condition in 1889, are now certainly not worse, and are probably better, than they were; and had I had similar information as to the state of the different fields near the Nira Canal, a definite conclusion might have been formed as to the progress of the evil. Baramati was, however, the only one of the areas on this canal visited by Mr. Ozanne and myself. Mr. Ozanne's notes do not include the exact position of the crop which he saw on the ground, but since I could find only two small plots of *juar*, besides the plantain grove in field No. 233, I think it may be safely stated that the evil has spread. It seems to me, therefore, that one of the first things which Government should take in hand is (1) the determination of the affected area, and (2) the determination

of the question whether the evil is spreading and at what rate. With regard to the first of these recommendations it is hardly for me to say how it should be done; for in the first place it will require careful discretion as to what fields have been thrown out of cultivation by the canal. I believe, however, that the Patel's books taken in conjunction with the position of the land in relation to the canal would afford a useful indication. The information can of course only be approximate.

24. Regarding the second suggestion, namely, the determination of the progress of the damage, I would recommend that certain specified areas should be chosen and the crops and other vegetation be actually recorded on the village maps, together with the condition of the uncropped area, whether swampy or not, the amount of erosion, etc., etc.

This work is not one which would absorb any extravagant amount of time. I may mention that in going over the fields at Baramati it occupied about three hours, and at Wadgaon, where I inspected eight fields and sketched the position of the crops in my note book, it occupied about one hour and a half. I do not consider that I did it very thoroughly: my time was limited; but the information gained in such a way as I have indicated would form an absolute record as to the state of the land.

I believe certain determinations of the amount of leakage from the canal have been made, and these should also provide a valuable indication as to whether it decreases or not.

25. I will now consider the possible methods of remedying the evil. In his notes Mr. Ozanne suggests drainage.

When land is water-logged, drainage is generally the proper remedy. But land is generally water-logged owing to surface drainage finding its way into some basin (if I may use the term) or into such an area in which, although the surface may be flat, the impervious sub-soil forms a basin, and out of which the water can only pass over the side. The usual method is then to make openings in the sides and let the water out. In such cases, however, the quantity of water passing in is less than that which can be made to pass out in the way indicated. The case under consideration seems to me to be different from that usually met with. As I examined the Baramati area, perhaps more carefully than any of the others, I will refer to it primarily.

In fields Nos. 239, 243 and 245 there are drains every 50-100 yards, and these are simply carrying off as much water as will run into them. The soil is, moreover, one which would, if it had an opportunity, easily drain itself; it is a fairly open soil and would not under ordinary conditions become water-logged. Moreover, it slopes away to the *nalla*. But it appeared to me that as fast as it let the water through, as much more came from the canal to replace it; in fact that the supply of water was never ending. If I am right in this conclusion, the more the land is drained the more water would leak in from the canal, and I, therefore, doubt if the method would be successful. But in addition to this there is the cost of drainage which is very great, and I raise the question whether drains could be laid

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for any sum which would be recovered. Circumstances naturally alter cases, and it would manifestly be a mistake to make the sweeping assertion that drainage would do no good in any of the areas, even of those which I visited. At Baramati, however, I came to the conclusion that, however much the land might be drained, so fast would water come in from the canal. Very much the same conclusions forced themselves upon me as I visited the other areas.

At Pimpli, for instance, the people have cut a drain down field No. 22 to the *nalla*, but, although it carries away the water as it passes into it, the benefit is not perceptible ; for the land is as bad as ever it was, and the soil (see notes) in the area of the drain is so bad that it is not safe to go near it. If the drainage were effecting a remedy, the soil near the drain should be drier than elsewhere. However, at field No. 139 in village Hol (by Wadgaon Bungalow) the people are trying drainage and it will be possible to observe here if any benefit ensues.

26. I must now refer to another point which I have mentioned, namely, the erosive action of storm water. In his notes Mr. Ozanne remarks that the people are putting up *bunds*, and that it is the very worst thing possible. The remark has only reference to the effect it may have on the drainage of the land and has no reference to the erosion. Even from Mr. Ozanne's point of view I cannot quite agree with him. We have here to do with water which percolates from the canal, that is, from *below*, not from above, the surface ; and although *bunds* would undoubtedly prevent some surface water from passing away at times during the monsoon, they will not interfere with sub-soil drainage of the canal water. The rainfall of this district (see Statistical Atlas of Bombay Presidency) is distinctly light. At Baramati it averages 22·7 inches, at Supa 20·3 inches, and at Indapur 24·8 inches ; the major part of this being spread over five months. But to my mind the people are not altogether wrong in making these *bunds*. The erosion is especially serious in these affected areas, which, as I have pointed out, are all *nallas* or drainage channels, containing what is probably the best soil and the deepest, and the people naturally wish to prevent the loss which they see going on. I saw many of these *bunds* and they are common to the country. Some had given way under the pressure of water. No doubt, owing to the condition of the soil, less rain-water soaks in than would otherwise be the case, and the *bunds* have more water to withstand.

Indeed this erosion must be considered only second to the leakage from the canal ; for not only is good soil being carried off and unculturable channels or ravines being formed, but it appears to me that there is also another evil. It is here that the leakage from the canal seems to be greater than elsewhere : the height of the water above the surface of the land is greatest and this difference is becoming greater ; or, in other words, the stratum of soil intervening between the canal water is gradually being lessened, and the important question arises, whether, as this process continues, the leakage will not increase ? I think it is a point worthy of consideration.

27. I have said that the people have good reason for making *bunds*.

The only further question which occurs to me is, whether these are *bunds* of the best description. They are simply earthen embankments carried across the drainage channels and would have to withstand a great weight of water whenever rain fell. In a note, *Agricultural Ledger No. 16 of 1894*, I have described a method of reclaiming ravine land, which **Captain Chapman**, on whose estate in Oudh I saw it, has called "Back terracing," and it has occurred to me whether this would not usefully replace these embankments which the people at present employ. I think the experiment might with advantage be made. In this case there is never any great weight of water to be withstood and the surface washing is reduced to a minimum.

28. It remains only for me now to consider the question whether any crops may be tried to be grown on these lands in their present state.

From my notes it will be seen that *babúl* and *tarwad* are growing healthily in most of the fields I examined. If only these could be grown it would be better than nothing; for if they provide little in the way of revenue, they not only prevent erosion, but by the action of their roots would probably open up the soil to the passage of some of the water.

But in addition to these I have met with three cases where crops are growing on these water-logged lands.

In field No. 233, Baramati, I found a small plantain grove: this looked healthy, and it is significant to notice that it has been doubled in size this year.

The second case that I met with was in field No. 262 at Karanje, where sugar-cane now is growing, although the field, like all around it, was thrown out of cultivation at first. The crop looked well, although it varied somewhat in height as might be expected.

The third case that came under my observation was at Nimbut where the people had tried rice in one field and it had succeeded, as the Canal Supervisor told me, better than any one expected.

The same crop or the same remedy may not prove effectual in all cases, but it seems to me most desirable that every encouragement should be given to the people in these affected tracts to grow something on the land, if that be only *babúl* trees.

29. Samples of soil were taken from certain of the fields and the following are the notes and analyses relating to them.

Baramati.—Field No. 229: This lies to the west side of the *nalla*. The only part of this which is now cultivated is the corner farthest from the river and *nalla*. The rest is waste; *babúls* (**Acacia arabica**) grow well and there is some grazing, but a very large part is barren, water-logged and salty. The soil is "black" (*regur*) and stony.

	Sodium Carbonate.	Sodium Sulphate.	Sodium Chloride.
	Per cent.	Per cent.	Per cent.
"A." Surface Soil	*Nil.*	·02	7·53
"B." Sub-soil	*Nil.*	·299	3·807

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Field No. 243: This field, which is situated near the canal, has a channel down the centre and another between it and the next field. Sample D. is one of the first 12 inches of surface soil. Water commenced to trickle into the hole as soon as it was made. The upper half of the field is waste, with a few bushes of *larwad* on it; the lower half is salty and swampy. The sample was taken from a spot where the salt appeared to be rather bad. The soil is *regur*.

	Sodium Carbonate.	Sodium Sulphate.	Sodium Chloride.
	Per cent.	Per cent.	Per cent.
D.	*Nil*	·096	·040

Village Hol.—Field No. 170: A sample of soil E. was taken from a field of sugar-cane at a spot where the crop was not very good. Water seemed to lodge here occasionally.

Field No. 139: This land adjoins field No. 170 and was affected by salty efflorescence. A sample G. was taken to a depth of 2 feet in the badly affected area.

Salts.—Three samples of the salts (with accompanying earth) were taken where they had accumulated badly; they are marked H., K., and L. in the accompanying statement.

	Sodium Carbonate.	Sodium Sulphate.	Sodium Chloride.
E.	(Total Salts ·052 per cent.)		
G.	*Nil.*	·189	1·038
H.	*Nil.*	26·24	1·516
K.	*Nil.*	27·52	·91
L.	*Nil.*	29·07	·69

Two samples of the water from the Nira Canal contained 7·28 and 10·08 grains of salts per gallon respectively, which consisted principally of Sodium and Magnesium Sulphates with only half a grain of Sodium Chloride.

Regarding these samples it will be seen that the salts *in the soils* consist of Sodium Sulphate and Chloride, the latter generally predominating. The salts H., K., L., were principally Sodium Sulphate, but this accumulation of the one salt at the surface has probably been controlled by conditions of crystallisation. Sodium Carbonate was absent from all the samples.

THE AMOUNT OF SALTS IN GOOD SOILS.

30. It seemed desirable to determine the amount of soluble Sodium salts which are usually present in good soils in order to form an opinion as to how much these *usar* lands contain in excess of that which may be considered normal.

As has become evident, really bad *usar* may contain from 1 to 2 per cent. of these salts in the first 6 inches of surface soil, but there is much *usar* land which contains considerably less than this amount.

The following statement exhibits the analyses which have been made to this end, from which it will be seen that although a small proportion of these Sodium salts forms a normal constituent of soils generally, as indeed might have been anticipated, the amount is usually quite small. The soil from village Mohammadpur,

Muzaffargarh District, was situated near land which was visibly affected by salts and it contained doubtless more than good soils do as a rule. It was nevertheless a piece of good land near the village and regularly cultivated.

The three samples of clay were analysed with a view to finding out if clays usually contain more soluble salts than arable land. Those from Dehra Dun and Cawnpur contained practically none. In that from Saharanpur there was certainly some appreciable amount though not much.

It will be evident, however, that good arable soils and clays rarely contain as much as ·1 per cent. of total Soluble Sodium Salts, and generally the amount is much less than this. Further it may be assumed that all the three salts, namely, Carbonate, Sulphate and Chloride of Sodium are commonly, though not always, present in such land.

POT CULTURES AND THE AMOUNT OF SALTS WHICH WILL DESTROY PLANT LIFE.

31. In 1895 and 1896 I attempted to determine which of the three salts, so constantly present in *usar* soils, is the most prejudicial to plant life. Good garden soil was taken and with it each of the three salts, Sodium Carbonate, Sulphate and Chloride, were mixed in the proportions ·1, ·2, ·4, ·7, and 1·0 per cent. On each occasion the plants were also grown in the soil without any salt. In the first year Maize, Gram, Wheat, Barley and Peas were sown in these artificial *usar* soils, and in the second year Maize, Cotton and *Arhar*, and Wheat, Barley and Gram.

The first set of experiments were made in small garden pots, the second in moderately sized boxes. The soils were kept moist by almost daily additions of distilled water, but the amount of this had to be kept down to a small limit, for of course no drainage could be permitted.

32. From these experiments one or two general conclusions may be drawn.

The only mixtures in which plant life was immediately destroyed were those soils which contained ·7 and 1·0 per cent. of Sodium Carbonate. In the presence of this amount of the salt generally speaking, a few seeds only germinated at all, and the plants died off in the course of a few days. In all other cases the salts, *i.e.*, Sodium Carbonate up to ·4 per cent. and Sulphate and Chloride up to 1·0 per cent. were not generally immediately fatal, though in many cases the plants died off later.

The effect of the salts on the germination was generally to retard it rather than to prevent it altogether.

In the case of the cereals, Maize, Wheat and Barley, the germination was first seriously affected by ·7 per cent. Sodium Carbonate or Sodium Sulphate. In one case Maize and Barley were held back by ·2 per cent. Sodium Chloride, but in the other cases this effect was only produced by ·4 per cent. of Sodium Chloride. The germination of cotton was affected by a like quantity. The germination of the

Salts in Good Soils.

	20-93.	430-94	457-94.	460-94.	402-95.	408-95.	409-95.	417.			
	Is on Sand Belt Good Soil.	Banthra, Lucknow. Good Soil.	Bahraich. Surface Soil.	Bahraich. Surface Soil.	Mohammadpur, Muzaffargarh, Panjab.	Average clay land on Chenab Canal.	Average loam, Chenab Canal.	Good loam, Kaliki.	Clay, Dehra Dun.	Clay, Saharanpur.	Clay, Cawnpur.
Sodium Carbonate . . .	...	·010	·005	·011	...	·041	...	...	·004	·033	·019
Sodium Sulphate . . .	...	·007	...	...	·088	...	...	...	·006	·076	*Nil.*
Sodium Chloride	...	·011	·007	·007	·052	...	·005	·029	*Nil.*	·014	*Nil.*
TOTAL SALTS .	·076	...	...	...	...	...	...	...	...	...	...

R, 67-70.

leguminous plants, Gram, Peas and *Arhar*, was interfered with by a somewhat smaller amount of the salts; ·2 to ·4 per cent. Sodium Carbonate, or Sodium Chloride, being sufficient to do harm, whilst of Sodium Sulphate ·7 per cent. generally proved harmful.

In the "after-growth" 0·2 per cent. Sodium Carbonate certainly caused harm in the majority of cases, though this amount did not actually prove fatal; ·4 per cent. was, however, quite fatal in the majority of cases.

The effect of Sodium Chloride was not quite as uniform as one might have wished. In the first experiments it proved unquestionably harmful in quantities so small as 0·1 per cent., but in the second series of experiments it did less harm and some of the plants grew in the presence of ·2 per cent. perfectly well.

Sodium Sulphate proved in both years to be less harmful than the Carbonate or Chloride, and in both the *kharif*, 1896, and the *rabi*, 1896-97, plants grew to the flowering stage in the presence of over ·5 per cent. of this salt.

Generally the leguminous plants suffered most readily, and of the cereals, Maize suffered least; this latter result *may* perhaps have been occasioned by the fact that more water was allowed to the plants in the *kharif* than in the *rabi*.

33. We may now compare these pot cultures with the conditions of fertility of some of the *usar* soils referred to in the former part of this paper.

Among the cases examined in the North-Western Provinces *usar*, at Kakwan (2 B.) we find grass growing in the presence of more than 1 per cent. of Sodium Carbonate in addition to smaller quantities of Sulphate and Chloride; at Ibrahimpur (3 B.) grass was growing in the presence of ·4 per cent. Sodium Carbonate. In the *usar* at Rasulabad (5) grass was growing in the presence of ·28 per cent. Sodium Carbonate and ·12 per cent. Sodium Sulphate.

At village Amramau (9) grass was growing in the presence of ·23 per cent. Sulphate in the surface soil and ·95 per cent. in the sub-soil. At Gursikran (14) grass was growing on the plots 35 and 24 which contained nearly ·2 per cent. Sodium Carbonate and about the same amount of Chloride. At Cherat grass is growing in the presence of as much as ·8 per cent. of Sodium Carbonate.

But although some grasses appear to exist in the presence of these amounts of salts, there is no evidence that cultivated crops can grow under such conditions. Analyses, as to the quantity of salts which seriously affect crops show fairly conclusively that so much may not be present without causing serious injury. In example 15 of the land at Gursikran it will be seen that wheat grew perfectly well in the presence of ·137 per cent. Sodium Carbonate in the top soil, but that it was destroyed by ·2 per cent. In example 5 at Rasulabad, a crop was growing perfectly in the presence of ·1 per cent. of Sodium Carbonate. At Mohammadpur, Muzaffargarh District, the soil contained ·088 Sodium Sulphate and ·052 Sodium Chloride, and, although no crop was on the field at the time, there was no doubt that it was regularly cultivated. Thus such evidence, as we have, indicates that crops

may be cultivated in the presence of ·1 per cent. of Sodium Carbonate, but that ·2 per cent. is sufficient to cause at least serious injury if not altogether to destroy the plant. There are no examples showing how much of the other salts may be present in a soil without doing serious harm.

34. The pot cultures which have been described indicate a conclusion in agreement with those made by American Chemists, namely, that the least harmful of these salts is the Sulphate and the most harmful the Carbonate. The Chloride is usually present only in subordinate amount.

The conclusion may, therefore, safely be drawn that the conversion of the Sodium Carbonate into Sulphate by the aid of gypsum would tend to minimise the evil effect of the Carbonate.

THE EFFECT OF CERTAIN SALTS, SUCH AS GYPSUM, ON USAR SOILS.

35. In a previous paragraph (3) of this paper I mentioned that one peculiarity of these *usar* soils is that they generally refuse to settle, after being stirred up with water. If, for instance, one part of an *usar* soil be shaken up with five parts of water, the sand of course settles immediately, but the clayey particles remain suspended in the water and days will often elapse before even the major portion of the clay subsides; indeed in some instances this part of the soil has formed quite a thick *cream* with the water and has refused to settle at all. In any case the clay never subsides perfectly and at best there eventually remains an opalescent liquid. On the other hand, if a good soil be submitted to this process, it settles rapidly.

Again, if any good soil or even a clay be mixed with water and then thrown on a filter (say 100 grammes of soil with 500 c. c. of water on a 6-inch filter bed consisting of a perforated porcelain plate with a piece of cotton cloth over it, with a "fall" of 8 or 10 feet to hasten the process), it will generally happen (naturally) that the first portion passing through will be muddy; the filtrate, however, rapidly clears and the remainder of the water will pass through clear and quite rapidly, often in 5 minutes.

In the case of most *usar* soils, however, this is not the case. With them it usually happens that muddy water comes through the filter bed for a considerable time, the process of filtration rapidly becomes slow, and although the water frequently eventually passes through clear, this is by no means always the case, and it is quite as common for the liquid which comes through to be *opalescent*. Again the process of filtration is usually *very* much slower than is the case with good arable land or clays. It may continue for an hour or two, or it may and frequently does take days for all the water to pass; it also often happens that the filtering process stops altogether at the end of a few hours.

If it be recollected that the quantity of soil named forms a layer of only about ¼ inch on the filter, that the water used measures only about 2½ inches and that the filtration referred to takes place under a pressure of 8 or 10 feet of water, it will be evident that *physically*

as well as chemically, these soils differ from ordinary good soils. It will also be at once apparent that in the case of such soils ordinary drainage conditions must have ceased to exist.

36. In the case of one of the soils which had yielded an opalescent extract, I wished to observe microscopically what its condition was, and after finding that it contained *solid* particles, I proceeded to see if they would become precipitated by the addition of salts in the same way as an acid causes many such light floating particles to subside. I added solution of Calcium Sulphate (gypsum). It acted perfectly and in a very few minutes the particles collected together and gradually subsided. The same thing occurred in a test tube and it was at once apparent that a clear extract of the soil could be obtained by this means. The cause of this effect was the next thing I studied, and one of the first questions which occurred to me was whether this subsidence of the particles had any relation to the effect which the Calcium Sulphate must have had on the Sodium Carbonate present in the extract. When solution of Calcium Sulphate is added to one of Sodium Carbonate, a simple chemical change occurs and Calcium Carbonate and Sodium Sulphate are formed.

In the next place I found that small quantities of such salts as Calcium Chloride and Barium Chloride, which also re-act in a similar manner with Sodium Carbonate, forming neutral salts, had precisely the same effect and precipitated the particles from the opalescent extract of the *usar* soil.

Experiments were now made on the entire soils. I added these salts to several *usar* soils (in water) which had filtered badly and I then found that the clayey particles simply coagulated in a most extraordinary manner and the whole very shortly subsided leaving the water perfectly clear and colourless. Moreover, after this treatment, the soils allowed filtration to proceed rapidly and perfectly. This effect was quite uniform in the case of the soils experimented with.

Other salts, such as Sodium Chloride and Sodium Sulphate, will likewise precipitate these *usar* soils. But the amount of them required for the purpose is very much larger than is the case with salts which re-act chemically with Sodium Carbonate, and the solution requires to be fairly concentrated.

The change was so sudden and generally complete that it seemed likely that it would occur suddenly after a *certain* definite quantity of the Calcium or Barium salt has been added.

37. I now carried out a quantitative experiment with a view to determining whether this peculiar curdling effect had any relation to the amount of Sodium Carbonate present. For this purpose I selected a set of soils in which the amount of Sodium Carbonate and other salts had been determined. It will be evident that if any relation exist between the curdling of the soil and the Sodium Carbonate present, the soil should coagulate when enough Calcium or Barium salt had been added to completely decompose the Sodium Carbonate. In each case the experiment was made as follows: 10 grammes of the soil was shaken up with 80 c.c. of

distilled water in a glass cylinder. Solution (of known strength) of the Calcium Sulphate, Calcium Chloride or Barium Chloride, as the case might be, was then added from a graduated burette to the soil and water, in small quantities at a time, and after shaking the soil and water, the cylinder was allowed to stand some 10 or 15 minutes between each addition of the salt in order to allow the effect to be observed. As soon as the coagulation became apparent, the quantity of the added Calcium or Barium salt was noted, and this quantity then calculated into its equivalent of Sodium Carbonate.

The results of this set experiments are set out in the accompanying statement, in which are also entered in the top line the amount of Sodium Carbonate which had been found by analysis. In four cases (Nos. 304, 305, 307, and 311) the amount of gypsum or other salt required to produce the coagulation was appreciably in excess of the amount of Sodium Carbonate present, but in the other eight cases the amounts approximate quite as closely as the circumstances of the experiments would admit. It is to be expected that an excess of the gypsum or other salt would be added before the coagulation occurred, and, moreover, this change is naturally not so perfect an indicator as is the case, for example, in alkalimetry, where a colouring matter is employed. But the experiment does indicate, I think, a very close connection between the coagulation and the amount of Sodium Carbonate, so much so that the conclusion may be drawn that it is due to the Sodium Carbonate that these soils generally offer so little facility to the passage of water and consequently hinder to a very great extent the natural process of drainage.

Statement showing the amounts per cent. (in terms of Sodium Carbonate) of certain Salts required to cause coagulation of Usar Soils.

No.	304.	305.	306.	307.	308.	309.	310.	311.	312.	313.	314.	315.
Sodium Carbonate present.	·044	·068	·072	·193	·416	·240	·137	·043	·340	·251	·332	·237
Calcium Sulphate . .	·145	·165	·103	·373	·393	·290	·207	·352	·310	·310	·372	·372
Calcium Chloride . .	·104	·145	·083	·270	·291	·270	·145	·125	·250	·250	·333	·353
Barium Chloride	·127	·148	·106	·339	·381	·212	·191	·169	·275	·297	·399	·399

38. But the most important practical conclusion which may be deduced from the foregoing series of experiments is the physical effect which gypsum has on these soils. It has been seen that this same effect is produced by other salts. So far as the Calcium Chloride and Barium Chloride are concerned, they may be now left out of consideration. They were merely included in the experiments to prove the general effect which those salts, which re-act with Sodium Carbonate, have on these soils. They are, however, not only far too expensive materials to think of employing them on the large scale, but also more or less prejudicial to plant life. Gypsum, however,

is a material which occurs in large amount in various parts of India, in the Himálaya, Salt Range, Central India, etc., and although, as will become presently evident, even then an expensive "cure" for *usar* land, it need not on that account be summarily dismissed from further consideration. It is likewise a substance which would do no harm to crops if present in even very much greater quantity than that now to be considered. Since it appears to be the case that an amount of gypsum is required by these soils to coagulate them, closely approximating to the amount of Sodium Carbonate present, we may calculate the amount of gypsum required to cure, or at least to open up to drainage water, certain land, the analyses of which have been quoted in the previous paragraphs.

It is necessary in the first place to know the weight of soil per acre which has to be dealt with, and from it to calculate the amount of gypsum equivalent to the Sodium Carbonate. A little consideration will show that it is not necessary to know this exactly, for in the first place the amount of salts in *usar* soils varies rapidly as is shown in some of the examples previously quoted, and secondly one does not know how far down the salts descend in the sub-soil, although the analyses quoted in this paper indicate that they are principally situated in the surface soil.

The weight of clay soil (in the dry state) per acre to a depth of 9 inches is stated by **Warington** to vary from 3 to 3·5 million pounds, which becomes 4 to 4·7 million pounds to the depth of 1 foot. **Schubler** calculated heavy clay land to weigh 3·25 million pounds to a depth of 1 foot. Some weighments which **Mr. Sabbiah**, Principal of the Agricultural School, Cawnpur, made for me, showed that the first 6 inches of a field which is in good manurial condition weighed 2·1 million pounds, the next 6 inches, however, was equal to 2·35 million pounds. In another field which was in poor condition, the first 6 inches of surface soil was equal to 2·42 million pounds per acre and the next 6 inches to 2·51 million pounds. Thus the first foot of soil in the good field works out to 4·15 million pounds, and that of the field in poor condition to 4·93, figures which are higher than what **Schubler** found, but approximate to those published by **Warington**. Assuming then that the *usar* land of the alluvial plains is generally similar to the field in poor condition or, say, 5 million pounds per acre for the first foot, and assuming a case in which the soil contains ·2 per cent. of Sodium Carbonate in the first foot, this will amount to 10,000lb of Sodium Carbonate. The amount of gypsum required to change this to Sulphate would be 16,000lb or (say) 200 maunds, and allowing ·1 per cent. of Sodium Carbonate for the second foot of soil the amount of gypsum required for the first 2 feet in the field comes to 300 maunds per acre. This is of course a large amount and would probably cost nearly as much as the land is worth. But there are doubtless very many fields more or less under cultivation, but sterile in parts, which might be cured by an application of a smaller amount of gypsum than that above mentioned. It may be of course that in practice it will be found sometimes unnecessary to neutralise the whole of the

Sodium Carbonate. For instance in a part of the *Usar* Reserve at Aligarh wheat grew perfectly in soil containing ·137 per cent. of Sodium Carbonate in the surface soil (*vide* paragraph 4), and if it should prove sufficient to reduce the quantity of Sodium Carbonate to 0·1 per cent., the cost would be much less than if the whole had to be converted into Sodium Sulphate.

In the case of some soils which I have treated with an amount of gypsum insufficient to convert the whole of the Sodium Carbonate, apparently the "coagulation" process had commenced, and the soil allowed water to pass more freely than before the treatment, but nevertheless more slowly than after the full equivalent of gypsum had been added.

Up to the present the experiments have been on a Laboratory scale only, but field experiments are now being commenced in the North-Western Provinces and the matter put on a practical footing. At any rate it may be safely assumed that in no case will any material benefit ensue from the application of merely 2 or 3 maunds of gypsum per acre.

39. Regarding the best method of applying gypsum, whether it will be necessary to grind it up to a powdery condition or whether it will be sufficient to break it into pieces the size of an egg; how deeply the land should be ploughed at the time of application, to what degree it may be advisable to mix the soil with the gypsum; how long it will take the gypsum to produce any effect on the sub-soil, are also questions which can only be answered by practical experiment.

One or two things may, however, be noted. The first is that gypsum is not very soluble in water, and that it is only after it becomes *dissolved* that it can exercise the physical and chemical effects which have been described. One part of gypsum requires 400 parts of water to dissolve it, and, as a very simple calculation shows, 6 inches of water on an acre of land weighs 1,360,000lb, this allowance of water would dissolve some 3,400lb or about 40 maunds of gypsum Much more than 6 inches of water cannot be put on land (by the aid of *bunds* of course) at one time, and consequently 6 inches of water would not dissolve a dressing of 200 or 300 maunds of gypsum at once.

But these calculations are valuable rather to show that a large amount of water would be desirable to assist in bringing the gypsum into a condition in which it can take effect, than to determine the absolute amount of water which might be necessary in any one case. The process which would follow the application of (say) gypsum in lumps the size of a nut on ploughed land may be pictured as follows. Water having been applied, it would dissolve the Sodium Carbonate in the surface soil and a small quantity of gypsum; that portion of gypsum which is then in solution re-acts with the Sodium Carbonate. Sodium Sulphate (a very soluble salt) and Calcium Carbonate are produced. The fact of the water now containing these two new salts does not prevent it from dissolving any more gypsum. On the contrary, this same water may now proceed to dissolve up another lot of

gypsum, which in its turn re-acts with more Sodium Carbonate and the process, so far as the water is concerned, might go on repeatedly.

But another circumstance plays an important part. Supposing some gypsum be placed at the bottom of a vessel and a solution of Sodium Carbonate poured upon it to a depth of several inches. The Sodium Carbonate which is in the immediate neighbourhood of the gypsum would re-act with it at once, but if the vessel be left at rest, the Sodium Carbonate in the upper strata of the vessel would only come into contact with gypsum very slowly, and consequently a considerable time would elapse ere the change between the whole of the gypsum and Carbonate became complete. If, on the other hand, means be employed to bring the Carbonate rapidly into contact with the gypsum, the change would proceed quickly. For instance, this would be the case if the vessel were constantly shaken.

Applying this to the supposed field experiment it may be assumed that if the land were ploughed (as is done for rice) whilst the water is in the *kiaris*, the rate at which the gypsum would be able to effect the desired chemical change in the Sodium Carbonate, and the physical one in the soil, would be materially augmented.

Incidentally this process of ploughing would probably assist in overcoming another difficulty.

Taking again the case of the lumps of gypsum in the glass vessel of Sodium Carbonate solution. As pointed out, in the first instance, the Carbonate touching the lumps of gypsum re-acts with the latter and there is produced Calcium Carbonate, and this is formed in part at least actually *at the surface* of each lump of gypsum. Calcium Carbonate is a very insoluble substance, much less soluble at least than the gypsum. The consequence is that on each lump of gypsum there is liable to be produced a covering of Calcium Carbonate, and this would, unless otherwise prevented, act as a sheath and stop the Sodium Carbonate and gypsum from coming into further contact with each other. Agitation and rubbing the lumps against each other or against other hard materials would break up such covering of Calcium Carbonate, and similarly ploughing the land would also assist in producing this effect.

Then, too, the smaller the lumps of gypsum, the larger will be the surface in contact with the water and, consequently, with the Sodium Carbonate.

Thus it will be seen that a plentiful supply of water, coupled with ploughing, may materially assist in giving the gypsum the opportunity to work its effect.

40. These considerations have to do principally with the surface soil. In the case of the sub-soil, where the plough cannot work and where (in such soils as are more or less impervious *at first* to water) the water cannot readily carry the gypsum, it is impossible to do much to assist matters. That the process will be slow is quite possible, if not probable. But having brought the gypsum into contact with the surface soil and thus causing those physical and chemical changes to take place which have been described, we may "rest on our oars" as it were. We have destroyed the Sodium Carbonate

in the surface soil and have provided a supply of gypsum for that which is in the sub-soil. If water brings the latter upwards, it is at once met by the gypsum and destroyed. If the irrigation water can penetrate the sub-soil it will carry some gypsum with it. Whilst the process is going on, some sort of a crop might be persuaded to grow in the surface soil.

The foregoing is a picture of what is *likely* to happen, drawn purely from a knowledge of the properties of the materials concerned.

41. One thing more may be alluded to. It has been fully explained, that the effect of gypsum is not to carry the Sodium Carbonate away, but to change it into another salt—the Sulphate. This, though less pernicious than the Carbonate, is nevertheless not harmless to plant life. Moreover, in many *usar* soils there exist also the Sulphate and Chloride of Sodium. To effect a perfect cure of *usar* it is necessary to *actually remove* these salts. If, as the Laboratory experiments already enumerated show, the soil, after treatment with gypsum, becomes pervious to water and drainage conditions establish themselves, it may then be hoped that these salts will be washed away from the reach of plant roots.

42. It has been suggested by some that underneath these *usar* lands are "pans" of impervious strata which are the cause of the very imperfect drainage. So far as I am aware, no single case has been described in which such a "pan" exists. Moreover, although I have searched for them in cuttings and river banks in the neighbourhood of *usar* plains, I have never been able to observe them. Nor is it altogether conceivable that such a state of things is the general cause of *usar* land. Some of these plains are of large extent and the "pan" corresponding to them would have to be very large indeed. Then, too, is such an explanation compatible with the existence of all the small patches of *usar* which occur in cultivated fields? Of course such a discussion is purely hypothetical and without supporting evidence.

On the other hand, the simple fact of these soils being frequently so impervious to water, as is proved by the filtration experiment described in paragraph 35, is quite sufficient to explain why the salts are not washed down, as is regularly the case in the cultivated areas. It must be admitted as at least possible that if this physical change (which gypsum undoubtedly effects on these soils) can be realised, one might confidently hope that the salts would be washed (more or less rapidly) into the sub-soil and away from the plants.

THE EFFECT OF ENCLOSING USAR LAND FROM GRAZING.

43. It has already been pointed out in paragraph 5 that where there is any material quantity of salts in *usar* soils, the major portion is situated in the first few inches of the surface soil.

In 1885 two considerable areas of *usar* land were taken up by the Agricultural Department, North-Western Provinces and Oudh,

near Aligarh. The one is situated at village Gursikran and has an area of 718 acres, the other at Cherat and measures 241 acres.

44. Various experiments were made at the latter place such as planting of trees and scraping off the salts annually, but the principal object with which both these areas were taken up was to see what would be the effect of enclosing the land from grazing. It was suggested that by this means the natural grasses might establish themselves again. Accordingly a fence was put round each and grazing prohibited. The immediate outcome of this procedure was a rapid growth of grass. In reporting on this point the Director, Botanical Department, Northern India, writes in 1887 with reference to Gursikran: "The prevailing grass is *kar-usara* which over the large portions of the ground grows in great luxuriance unmixed with any other kind of vegetation. Some of the blocks are almost entirely bare and efflorescent; others contain nothing but *usar* grass; whilst in others there is a mixed vegetation, including various sized patches of *dub* grass which appears to be rapidly spreading. All these various conditions present a corresponding series of changes which the vegetation over the whole area has been undergoing during the time it has been enclosed and protected."

And regarding the area at Cherat the same officer reports: "The effect of enclosing this piece of land, even for so short a time, has been directly beneficial in stimulating the growth of the natural grasses. The *kar-usara* or *usar* grass (a species of **Sporobolus**) is rapidly extending over parts that were absolutely bare, whilst *dub* **(Cynodon dactylon)** and other valuable fodder grasses are spreading in proportion."

As the grasses extended, the salts apparently disappeared from the surface more or less, and the question naturally occurred, "Are the grass roots opening up the soil so as to re-establish natural drainage conditions?"

45. No samples of the soil of either of these "*usar* Reserves" were selected when the land was first taken up, and the only evidence of their former condition which was at my disposal when I visited Aligarh in 1893 were some illustrated sketches and notes which **Mr. Duthie** had made shortly after the land was enclosed and which he very kindly lent me.

From these, however, it was possible to find spots which were not only devoid of grasses in 1888, but on which a plentiful crop of *Reh* was present.

Judging by the analyses of land covered with *Reh*, which have been already quoted, one may assume that the amount of salt must have been something approaching 1·0 per cent.

In 1893, the grasses had spread over plot 35 and no salt was visible. Plot 24 was one of several on which rain water had been annually retained by means of an embankment, and the land was destitute of grass, but there was also no visible sign of salt.

The analyses have already been detailed in paragraph 4 (14), and it will be seen that not only is there comparatively little salt in the surface soil, but that the amount *increases* somewhat in the sub-soil

of plot 35. In the land outside the *usar* Reserve [*vide* 4 (14)] there was considerably more salt in the surface and sub-soil than in that of the two plots named. Again at the second place in this *usar* Reserve [*vide* 4 (15)] from which samples have been analysed, it will be seen that there is less salt in the surface than in the sub-soil. Finally at Cherat where grazing has been excluded and the grasses encouraged, much the same thing is evident; there is as much salt in the sub-soil as in the surface soil.

46. It would seem clear, therefore, that the enclosure from grazing and the consequent growth of grass has caused the salts to become diffused into the sub-soil, and, although the process is a very slow one, one might anticipate that eventually these salts may become spread throughout such a depth of soil as to reduce that in the surface to a quantity which will no longer prevent the growth of crops.

47. ***Conclusion.***—The conclusions which may be drawn from the foregoing work may now be briefly summarised:—

(1) The presence of an injurious amount of Sodium Salts in the surface soil is not confined to land in the North-Western Provinces and Oudh and the Panjab, but the same phenomenon has established itself in at least two other places in the Bombay Presidency. It would appear probable, however, that the occurrence of the salts in the black soil tracts in the neighbourhood of the Nira Canal is due solely to percolation from the canal.

(2) In the North-Western Provinces and Oudh the salt which is usually present in largest amount is the Carbonate. In the Muzaffargarh District of the Panjab and on certain lands in the neighbourhood of the Chenab Canal, the principal salt is likewise the Carbonate. In the Ferozepur District, at Lahore, and on the upper part of the Chenab Canal area, the salt which is usually present in greatest amount is the Sulphate.

In the *usar* land of the Kaira District, Gujarat, and in the land on the Nira Canal the principal salt is the Chloride.

(3) These Sodium Salts are almost uniformly concentrated in the first few inches of surface soil, the amount in the sub-soil being generally considerably less.

(4) The amount of Sodium Salts in the surface soil of *bad usar* land rarely exceeds 2 per cent. and is often much less.

(5) All the three Sodium Salts, Carbonate, Sulphate and Chloride, are commonly present in good arable land and in clays; the amount of them is, however, usually quite small, sometimes rising to as much as one-tenth per cent., but generally to much less than this.

(6) Enclosing land from grazing and thus encouraging the grasses to grow, causes, or allows, the salts to descend from the surface soil and to become distributed in the sub-soil; the rate at which this distribution occurs is not known, but it is evidently slow.

(7) The pot-culture experiments which have been made, indicate that ·2 per cent. of Sodium Carbonate causes injury to cultivated plants and this result is incidentally confirmed by certain examples taken from the soils of fields. Of Sodium Chloride, ·2 per cent. probably does harm; ·4 per cent. is certainly pernicious. Of Sodium

Sulphate, ·5 per cent. is probably not harmful to cereals. Plants of the leguminous order appear to be more readily affected by Sodium Salts than are the cereals.

(8) The very imperfect conditions of drainage, which exist in *usar* lands are probably occasioned not by an impervious "pan" below ground, as has been assumed by some, but by the condition in which these *usar* soils have arrived. The cause of this condition is probably the Sodium Carbonate present; if the Sodium Carbonate be destroyed, these soils become pervious to water and admit of rapid drainage.

The Sodium Carbonate may be destroyed by various means; one, which is perfectly successful, consists in the application of gypsum to the soil.

But whether it would be necessary to apply enough gypsum to convert the whole of the Sodium Carbonate into Sulphate, or whether a less quantity would prove sufficient, remains to be demonstrated by field experiments.

G. I. C. P. O.—No. 294 R. & A.—13-1-97.—2,200.—W. B. G.

All communications regarding THE AGRICULTURAL LEDGER should be addressed to the Editor, Dr. George Watt, Reporter on Economic Products to the Government of India, Calcutta.

The objects of this publication (as already stated) are to gradually develop and perfect our knowledge of Indian Agricultural and Economic questions. Contributions or corrections and additions will therefore be most welcome.

In order to preserve a necessary relation to the various Departments of Government, contributions will be classified and numbered under certain series. Thus, for example, papers on Veterinary subjects will be registered under the Veterinary Series. Those on Forestry, in the Forest Series. Papers of more direct Agricultural or Industrial interest will be grouped according as the products dealt with belong to the Vegetable or Animal Kingdom. In a like manner, contributions on Mineral and Metallic subjects will be registered under the Mineral Series.

This sheet and the title-page may be removed when the subject-matter is filed in its proper place according to the letter and number shown at the bottom of each page.